Thermal Charm Production By Massive Gluons and Quarks*

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At ultrarelativistic energies, nucleus-nucleus collisions can be described by parton interactions. During the evolution of the parton system, many collective phenomena can appear. As predicted by finite temperature QCD, the quarks and gluons in the medium can acquire a temperature-dependent mass,

$$m^2_{q,\mathrm{th}}(T) = \frac{g^2T^2}{6} \quad (1)$$

$$m^2_{g,\mathrm{th}}(T) = \frac{g^2T^2}{3}(1+\frac{N_f}{6}) \quad (2)$$

where g is the strong coupling constant, also temperature dependent. These temperature dependent masses both affect the time evolution of the system and lower the threshold for charm production in the medium. An enhancement of charm production could be measured if this thermal charm yield is comparable to that from the initial nucleon-nucleon collisions.

Primary charm production from the initial nucleon-nucleon collisions can be substantial. In the most recent calculation of initial charm production [1] in Au+Au collisions, extrapolated from pp collisions, a total of 9 (450) initial $c\overline{c}$ pairs were produced at RHIC (LHC) due to the behavior of the parton densities at low x.

We investigate thermal charm production in a fully equilibrated, longitudinally expanding QGP with massive quarks and gluons at RHIC and the LHC. We compare our results with those from zero mass quarks and gluons. We assume both a pure gluon gas and a quark-gluon plasma and distinguish between parton gas and minijet gas initial conditions.

The largest charm production was found when a parton gas was assumed because the characteristic thermalization time was $\tau_0 = 0.5 - 0.7$ fm. Then the parton gas lifetime was long, more then 10 fm. At RHIC we obtained a 30-40% enhancement with massive gluons and quarks while at the LHC, a 50-100% enhancement may be expected. With $m_c = 1.2$ GeV, the charm mass used in [1], we obtained 4.9 secondary charm quark pairs at RHIC and 245 charm pairs at LHC. Note that these numbers, upper limits on secondary charm production, are similar to the expected initial charm production [1].

The lifetime of the minijet gas is significantly shorter than the parton gas due to the short thermalization time, $\tau \sim 0.1$ fm. This difference strongly reduced the charm yield from the minijet gas compared to the parton gas. The fast expansion reduces the influence of the massive quasi-particles at RHIC where the initial temperature of the minijet gas was also less than that of the parton gas. The enhancement was typically 20% with massive quarks and gluons but the total yield, 0.016 pairs from the quark-gluon gas, was very small compared to the initial charm rate. Although the expansion was also fast at the LHC, the much higher initial temperature, $T_0 \approx 1$ GeV, generated large charm production rates. We obtained 38 secondary charm quark pairs from a quark-gluon gas and 100 pairs from a gluon gas. The minijet gluon gas result is only a factor of two smaller than the corresponding parton gas yield at LHC.

Our results show that the massive excitations of the quarks and gluons significantly enhance charm production by the plasma as well as slowed the expansion of the system. Thus charm enhancement in heavy ion collisions could be an excellent probe of the presence of collective excitations in the deconfined plasma.

[1] S. Gavin, P.L. McGaughey, P.V. Ruuskanen and R. Vogt, Phys. Rev. **C54** (1996) 2606.

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